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Flexible Disc for Magnetic Recording

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(57) Claims

1 A flexible disc for magnetic recording provided with a magnetic recording layer comprising a metal thin film on a polyester film substrate, said flexible disc for magnetic recording comprising a metal thin film characterized in that the polyester film is essentially a biaxially-oriented film comprising poly-1,4-cyclohexylene dimethylene terephthalate, wherein the maximum coefficient of temperature-induced expansion in a plane that includes the lengthwise and widthwise directions of the film is 9 to 35×10^{-6}°C^{-1}, the maximum coefficient of moisture-induced expansion is 0 to 8.0×10^{-6}(% RH)$^{-1}$, the difference between the maximum and minimum coefficients of temperature-induced expansion is 0 to 8.0×10^{-6}°C^{-1}, and the difference

between the maximum and minimum coefficients of moisture-induced expansion is 0 to $3.0 \times 10^{-6} (\% \text{ RH})^{-1}$.

Detailed Description of the Invention

Field of Industrial Utilization

The present invention relates to a flexible disc for magnetic recording provided with a magnetic recording layer comprising a metal thin film that is capable of preventing tracking errors, more particularly to a flexible disc for magnetic recording provided with a magnetic recording layer comprising a metal thin film that is capable of high track-density recording.

Prior Art

Preventing tracking errors by providing a special circuit (track servo, or the like) for track detection, or a mechanism for inhibiting temperature change in a common magnetic flexible disc recording/reading device itself is conventionally known. The recording/reading device naturally becomes complex with these means, so they are not used in general applications. In actual practice, means are adopted in which a magnetic flexible disc is manufactured and tracking errors are prevented by means of selecting to the extent possible materials with a low coefficient of thermal expansion and coefficient of moisture-induced expansion for the substrate film and the magnetic material.

Tracking errors occur, nevertheless, even when this type of magnetic flexible disk is used at high temperatures (40 to 50°C) and/or high humidity (about 80% RH). A magnetic flexible disc recorded under a low temperature (about 10°C) or a low humidity (about 25% RH) in particular has a drawback in that tracking errors occur when the disc is read under an atmosphere of normal temperature (about 25°C) and a normal humidity (about 60% RH). Problems wherein the S/N ratio worsens and the output envelope is reduced by such tracking errors remain unresolved.

In recent years in particular, a method whereby a metal thin film is formed as a magnetic recording layer on a thermoplastic (which is a nonferrous carrier) by vacuum precipitation such as vacuum vapor deposition or sputtering, and this metal thin film is allowed to serve as the magnetic recording material; a method in which a metal thin film is obtained by means of

electroless plating; and other methods have been proposed as methods that do not involve the use of a binder as a high density magnetic recording medium.

The magnetic flexible disks that are provided with a magnetic recording layer comprising a metal film are often used to carry out so-called vertical magnetic recording in which recording in performed by means of magnetizing in the direction of film thickness of the magnetic recording medium, but simply improving these is insufficient for increasing the density of the magnetic recording, and high density magnetic recording should also be achieved at the same time by satisfying improvements in the track density that are attributable to the coefficients of temperature- and moisture-induced expansion of the substrate film.

A flexible disc for magnetic recording comprising a metal thin film capable of such high track density recording has not yet been obtained.

Objects of the Invention

The present inventors, as a result of thoroughgoing research aimed at resolving the above-stated drawbacks, perfected the present invention having discovered that a film with high dimensional stability can be obtained by means of adjusting the coefficients of temperature- and moisture-induced expansion of the biaxially-oriented film comprising poly-1,4-cyclohexylene dimethylene terephthalate, and that tracking errors can be prevented by manufacturing a flexible disc for magnetic recording comprising a metal thin film serving as the substrate.

An object of the present invention is to provide a flexible disc for magnetic recording comprising a metal thin film that has been improved such that the service range of atmospheric conditions of temperature and humidity is expanded, and tracking errors do not occur under conditions of high temperature and high humidity.

Another object of the present invention is to provide a disc for magnetic recording comprising a metal film that has high dimensional stability with respect to temperature and humidity, wherein this disc can be provided with a higher density of magnetic recording, and improved track density in particular.

Constitution of the Invention

The present invention is a flexible disc for magnetic recording provided with a magnetic recording layer comprising a metal thin film on a substrate of biaxially-oriented film comprising

a polyester based on poly-1,4-cyclohexylene dimethylene terephthalate in which 80% or more of the acid component is composed of terephthalic acid, wherein the maximum coefficient of temperature-induced expansion in a plane that includes the lengthwise and widthwise directions of the film is 9 to 35×10^{-6}°C^{-1}, the maximum coefficient of moisture-induced expansion is 0 to $8.0 \times 10^{-6}(\% \text{ RH})^{-1}$, the difference between the maximum and minimum coefficients of temperature-induced expansion is 0 to 8.0×10^{-6}°C^{-1}, and the difference between the maximum and minimum coefficients of moisture-induced expansion is 0 to $3.0 \times 10^{-6}(\% \text{ RH})^{-1}$.

This flexible disc for magnetic recording may be obtained by means of using vacuum deposition, sputtering, ion plating, C.V.D. (Chemical Vapor Deposition), or electroless plating, or other method on a substrate of a biaxially-oriented polyester film based on poly-1,4-cyclohexylene dimethylene terephthalate.

The biaxially oriented polyester film based on poly-1,4-cyclohexylene dimethylene terephthalate may be manufactured by means of suitably controlling the film formation conditions so as to satisfy the above-described coefficients of temperature- and moisture-induced expansion.

The flexible disc for magnetic recording of the present invention is composed of a substrate film and a magnetic layer comprising a metal thin film. Examples of means for forming such a metal thin film include vacuum vapor deposition, C.V.D (Chemical Vapor Deposition), electroless plating, and other methods, but all conventionally known methods may be used to form the metal thin film.

In the case of vacuum vapor deposition, vapor-deposition metal in a tungsten boat or an alumina hearth is vaporized by means of resistance heating, high frequency heating, electron beam heating, or another heating method under a vacuum of 10^{-4} to 10^{-6} Torr, and deposited on the carrier. Fe, Ni, Co, and alloys thereof are normally used as the vapor-deposition metal. The reactive evaporation method in which Fe is evaporated in an O_2 atmosphere to obtain an iron oxide thin film may be applied in the present invention. In the case of ion plating, a DC glow discharge or an RF glow discharge is generated, and metal is evaporated during discharge in an atmosphere in which an inert gas is the principal component under a vacuum of 10^{-4} to 10^{-3} Torr. Ar is normally used as the inert gas. In the case of sputtering, a glow discharge is created in an atmosphere in which Ar is the principal component under a vacuum of 10^{-3} to 10^{-1} Torr, and atoms on the target surface are removed by the generated Ar ions. DC diode and triode

sputtering, and high frequency sputtering are methods that may be used to generate a glow discharge. Magnetron sputtering that makes use of a magnetron discharge may also be used.

The thickness of the magnetic thin film must be sufficient to provide adequate signal output for a high-density magnetic recording device. The thickness of the magnetic thin film in common practice is therefore between 0.02 to 1.5 μm (200 to 15,000 Å), although this depends on the application.

Examples of methods for forming a magnetic thin film for lengthwise recording include vapor deposition (including thermal vapor deposition, electron beam vapor deposition, and other vapor deposition methods), sputtering (including DC diode sputtering, high frequency sputtering, and other sputtering methods), and other methods. In the case of vapor deposition, shape anisotropy and crystal magnetic anisotropy are established in the horizontal direction of the tape by continuously performing oblique deposition of ferromagnetic material such as Co on the nonferrous plastic carrier so that the axis of easy magnetization is oriented in the horizontal direction of the tape, and performing repeating lamination. The total thickness of the metal thin film is therefore about 0.02 to 0.5 μm (200 to 5,000 Å).

In addition to the method of forming a magnetic thin film for lengthwise recording as described above, a vertical magnetic recording method may also be used for a flexible disc as a technique capable of yielding high density digital recording. In this method, a suitable amount (10 to 20%) of Co may be mixed in Cr to allow the axis of easy magnetization to be oriented in the vertical direction of the nonferrous carrier, the reduced magnetic field that is generated is inhibited, the axis of easy magnetization is oriented in the vertical direction, and recording is performed in the direction that is perpendicular to the substrate surface.

In the case of the sputtering method, a Co-Cr alloy with a thickness of 0.2 to 1.5 μm is used. Here, a magnetic flux focusing thin film composed of Permalloy (Fe-Ni), Supermalloy, or another highly magnetically permeable material may be disposed between this nonferrous carrier and the magnetic recording layer having an axis of easy magnetization in the vertical direction. The highly magnetically permeable material serving as the magnetic flux focusing body is formed by sputtering and is a thin film with a low coercive force (50 Oe or less) and a film thickness of 0.1 to 1 μm (1,000 to 10,000 Å). The Co-Cr film of the magnetic recording layer is formed to a thickness of about 0.2 to 1.5 μm (200 to 15,000 Å) at this time.

It should be noted that the front and back of the substrate film should have at least one magnetic recording layer comprising a metal thin film, but may also have a soft magnetic layer composed of an Ni-Fe alloy thin film or the like, a suitable adhesive layer between the substrate film and the metal thin film, or a protective layer on the metal thin film, as disclosed in JP (Kokoku) 58-91.

The polyester based on poly-1,4-cyclohexylene dimethylene terephthalate and used as the substrate film in the present invention is one in which the dibasic acid component has a terephthalic acid content of 80 mol% or more, and the glycol component is a glycol selected from cis- and trans-isomers of 1,4-cyclohexylene dimethanol. Examples of the dibasic acid component other than terephthalic acid include isophthalic acid, phthalic acid, adipic acid, sebacic acid, succinic acid, oxalic acid, and other dibasic acids, and isophthalic acid is preferred.

The 1,4-cyclohexylene dimethanol used in the present invention is manufactured by means of the catalytic reduction of dimethyl terephthalate or terephthalic acid, and either of these methods may be used.

The ratio of the cis- and trans-isomers of 1,4-cyclohexylene dimethanol is not particularly limited, but is preferably in the range of 4/6 to 0/10 (cis/trans).

Stabilizers such as phosphoric acid, phosphorous acid, and esters thereof; delusterants such as titanium dioxide, particulate silica, kaolin, calcium carbonate, calcium phosphate; and lubricants or the like may also be contained in the polyester based on poly-1,4-cyclohexylene dimethylene terephthalate.

The biaxially-oriented polyester film based on poly-1,4-cyclohexylene dimethylene terephthalate and used in the present invention has a maximum coefficient of temperature-induced expansion of 9 to 35×10^{-6}°C^{-1}, but preferably 9 to 25×10^{-6}°C^{-1} in a plane that includes the lengthwise and widthwise directions of the film; a maximum coefficient of moisture-induced expansion of 0 to 8.0×10^{-6}(% RH)$^{-1}$, but preferably 0 to 5.0×10^{-6}(% RH)$^{-1}$; a difference between the maximum and minimum coefficients of temperature-induced expansion of 0 to 8.0×10^{-6}°C^{-1}, but preferably 0 to 5.0×10^{-6}°C^{-1}; and a difference between the maximum and minimum coefficients of moisture-induced expansion of 0 to 3.0×10^{-6}(% RH)$^{-1}$, but preferably 0 to 2.5×10^{-6}(% RH)$^{-1}$. When the coefficients of temperature- and moisture-induced expansion of the film substrate satisfy these ranges, tracking errors on the flexible disc can be prevented, and service in a wide range of temperatures and humidity is made possible. When the coefficients of

temperature- and moisture-induced expansion exceed the above-stipulated ranges, playing back the flexible disk for magnetic recording at a temperature that is different from the atmosphere in which recording occurred will result in the generation of tracking errors that are caused when stretching differs from the center of the magnetic flexible disc due to the difference between the coefficients of temperature- and moisture-induced expansion, and the recording tracks and the magnetic head will become misaligned. As a result, output changes and dropouts occur.

In current art, polyester films based on polyethylene terephthalate and most commonly used in flexible discs for magnetic recording have a maximum coefficient of temperature-induced expansion of about $17 \times 10^{-6} {}^\circ C^{-1}$, a difference between the maximum and minimum coefficients of temperature-induced expansion of about $8.0 \times 10^{-6} {}^\circ C^{-1}$, and essentially the same coefficient of temperature-induced expansion as that of a recording and playback device when the coefficient of temperature-induced expansion is taken into account, but it is impossible to completely prevent track misalignment due to differences among the coefficients of temperature-induced expansion in different directions within a plane. With regard to the coefficient of moisture-induced expansion, track misalignment brought about by marked changes in humidity (about 11×10^{-6} $(\% \text{ RH})^{-1}$) are quite considerable because the coefficient of moisture-induced expansion of the recording and playback device is assumed to be 0. By contrast, using the biaxially-oriented polyester film based on poly-1,4-cyclohexylene dimethylene terephthalate and used in the present invention allows track misalignment associated with the coefficient of temperature-induced expansion and the coefficient of moisture-induced expansion to be made smaller than in a commonly used biaxially-oriented polyester film based on polyethylene terephthalate; and by decreasing the difference between the maximum and minimum values of the coefficient of temperature-induced expansion and the difference between the maximum and minimum values of the coefficient of moisture-induced expansion, track misalignment can be further inhibited, and normal operation can be maintained in an atmosphere with a wide range of temperature and humidity. This substrate film allows a flexible disc for magnetic recording of higher density to be obtained.

The method of producing a polyester film based on poly-1,4-cyclohexylene dimethylene terephthalate and designed to obtain the above-stated expansion characteristics may be the same as methods for producing polyethylene terephthalate films or other regular polyester films. Melt extruded undrawn film may be created by means of the T-die method, the inflation method, or

another method, and then biaxially drawn to form a biaxially oriented film. The drawing temperature at this time may be set to substantially the same conditions as those for the production of polyethylene terephthalate film, but because the glass-transition temperature and the melting point vary in accordance with the quantity of terephthalic acid contained in the polyester based on poly-1,4-cyclohexylene dimethylene terephthalate, the temperature of the casting drum and the melting temperature must be suitably selected to correspond thereto. The drawing temperature is normally between 80 and 140°C; and the draw ratio should be 3.0 to 5.0 times in the longitudinal direction, but is preferably 3.5 to 4.5 times, and should be 3.0 to 5.0 times in the lateral direction, but is preferably about 3.5 to 4.5 times. The film obtained in accordance with the present invention and provided with only a minimal tracking misalignment due to temperature- and moisture-induced expansion can be produced by means of heat-setting the obtained biaxially oriented film for 1 to 100 seconds at 150 to 260°C (preferably 180 to 250°C). The biaxially oriented polyester film based on poly-1,4-cyclohexylene dimethylene terephthalate in accordance with the present invention is, however, not limited to solely being obtained by means of such methods. The biaxially oriented film of the present invention may be formed to a suitable thickness depending on the application thereof, but the thickness is normally selected from a range of about 25 to 125 μ. The thickness is naturally not limited to this range.

The methods of measuring the characteristic values in the present invention are described below.

(1) Coefficient of temperature-induced expansion

Measurement was performed by placing a fixed-load drawing test machine (model ITL2) manufactured by NJS Corp. (current name: Lasertec) in a thermo-humidistat. The coefficient of temperature-induced expansion was measured by heat-treating the measurement sample under prescribed conditions (70°C for 30 minutes, for example), mounting the sample on the test machine, and reading the dimensional changes between 20°C and 40°C (relative humidity: 60% RH). The original sample at this time had a length of 505 mm and a width of 1/4 inch. The weight applied during measurement was fixed at 5g per 1/4 inch. In the case that a long sample cannot be obtained, measurement may also be performed using a thermomechanical analysis apparatus (TM-3000) manufactured by Shinku Riko (current name: ULVAC-RIKO, Inc.). The TM-3000 was used when calculating the difference between the maximum and minimum values of the coefficient of temperature-induced expansion. The dimensions of the sample were a

length of 15 mm, and a width of 5 mm; and the difference between the maximum and minimum values of the coefficient of temperature-induced expansion can be known by reading the dimensional variations at a temperature of 10°C and humidity of 0% RH, and at a temperature of 40°C and a relative humidity of 0% RH. The values obtained by means of both measuring methods were in perfect agreement, so either measuring method may be used.

(2) Coefficient of moisture-induced expansion

A fixed-load drawing test machine manufactured by NJS Corp. was used in the same manner as when calculating the coefficient of temperature-induced expansion; and the coefficient of moisture-induced expansion was measured by means of heat-treating the mounted sample under prescribed conditions (temperature: 40°C; relative humidity: 90%), and reading the dimensional changes between relative humidity levels of 30% and 70% (temperature 20°C). In the case that a long sample cannot be obtained, the sample may be placed in a thermomechanical analysis apparatus manufactured by Shinku Riko, in the same manner as when measuring the coefficient of temperature-induced expansion, and measured under the above-noted conditions. In this case as well, the values obtained by means of both methods were in perfect agreement.

(3) Tracking misalignment test (temperature variation)

The following methods may be used for the tracking misalignment test. A magnetic recording layer was formed on both sides of a substrate film by means of sputtering a metal thin film, the flexible disc comprising a metal thin film punched out to form a disc shape was magnetically recorded using a ring head at a temperature of 15°C and a humidity of 60% RH, and the maximum output and the output envelope of the magnetic sheet were measured at that time. The atmospheric temperature was subsequently to a level corresponding to a temperature of 40°C and a humidity of 60% RH; the maximum output and the output envelope of the magnetic sheet were measured at that temperature; the output envelope at the temperature of 15°C and the humidity of 60% RH was compared with the output envelope at the temperature of 40°C and the humidity of 60% RH; and the tracking condition was determined. The smaller this difference is, the better the tracking characteristics are. Poor tracking is designated by "×" when this difference is 3 db or more, and results that are within 3 db are designated by "O."

(4) Tracking misalignment test (humidity variation)

Recording was performed under an atmosphere having a temperature of 25°C and a relative humidity of 20% in the same manner as the previous section, the atmospheric conditions

were kept at 25°C and a relative humidity of 70%, and the output envelopes when the relative humidity was 20% (25°C) and 70% (25°C) were compared. The quality of the tracking was evaluated in the same manner as the previous section. The evaluation method was the same as section three.

Working Examples

The present invention is subsequently described in detail with working examples.

Working examples 1 to 4, and Comparative examples 1 and 2

Terephthalic acid (85 mol%) and isophthalic acid (15 mol%) were used as the dibasic acid component, 1,4-cyclohexylene dimethanol was used as the glycol component, and these were placed in an autoclave with titanium oxide (0.05 mol%) as a catalyst. The system was heated under agitation and transesterified, and subsequently subjected to polycondensation to obtain a polyester that was based on poly-1,4-cyclohexylene dimethylene terephthalate and comprised 1,4-cyclohexylene dimethanol, terephthalic acid, and isophthalic acid.

Polycyclohexylene-1,4-dimethylene terephthalate comprising 100% terephthalic acid and 100% 1,4-cyclohexylene dimethanol was also polymerized in the same manner. Polyethylene terephthalate was polymerized with a regular method as a comparative example. These two types of polyester were melt-extruded at 300°C to obtain an undrawn film having a thickness of 1,050 μ. The film was subsequently drawn 3.3 to 3.7 times in the longitudinal direction at 90 to 120°C, 3.4 to 3.8 times in the lateral direction at 100 to 130°C, and further heat-set for 10 to 30 seconds at 200 to 240°C to obtain biaxially-oriented films that had a thickness of 75 μ and were produced in different conditions. An Ni-Fe alloy film having a thickness of 0.5 μ and a Co-Cr alloy film having a thickness of 0.4 μ were formed in sequence with a sputtering method (using the counter targets disclosed in JP (Kokai) 57-158380 and other publications) on both surfaces of the biaxially-oriented films that were obtained in such a manner, to form a double-sided two-layer medium.

In other words, the Ni-Fe alloy film was formed by means of sputtering at a mean deposition rate of 0.2 μ/min and an argon gas pressure of 1.0 Pa (pascals) while the substrate sheet was allowed to travel on a rotating drum (diameter: 350 mm; temperature: 23°C) that was disposed to the side of both targets using a counter target-type sputtering apparatus in which two

Ni-Fe alloy targets (Ni: 81 wt%, 330 mm × 150 mm) were set in opposition with a spacing of 120 mm; and an Ni-Fe alloy film was sequentially formed on both surfaces to a thickness of 0.5 μ.

The Co-Cr alloy film was then sequentially formed on both surfaces to a thickness of 0.4 μ by means of sputtering at a mean deposition rate of 0.2 μ/min while the sheet on which the Ni-Fe alloy film was formed was allowed to travel on a rotating drum (maintained at a temperature of 110°C) by means of the same apparatus as above using two Co-Cr alloy targets (Cr: 17 wt%), and a double-sided two-layer medium was fabricated.

The medium was thereafter cut out to form a flexible disc for magnetic recording whose outside diameter was 20 cm and whose inside diameter was 3.8 cm, and the disc was recorded to and played back from with a recording and playback device. The sheet recorder was rotated at 360 rpm, and the position of the magnetic head was set to 8 cm from the center of the disc. The track width was 300 μ, and the head material was ferrite. A 1-MHz signal was recorded to the flexible disc for magnetic recording under predetermined conditions, the recorded signal was played back under predetermined conditions, and the difference in the output envelope was measured. The envelope was 0.2 dB or less when the conditions of this flexible disc for magnetic recording were 15°C and 60% RH, and 25°C and 20% RH.

The coefficients of temperature- and moisture-induced expansion, and tracking misalignments for the polyester based on poly-1,4-cyclohexylene dimethylene terephthalate were tested while varying the film production conditions, and the results thereof are shown in Table 1.

Table 1

		Maximum coefficient of temperature-induced expansion (°C^{-1})	Difference between maximum and minimum coefficients of temperature expansion (°C^{-1})	Maximum coefficient of moisture-induced expansion (%RH^{-1})	Difference between maximum and minimum coefficients of hygroscopic expansion (%RH^{-1})	Envelope of playback at 40°C	Envelope of playback at 70 %RH
Working example 1	Terephthalic acid (85 mol%) Isophthalic acid (15 mol%) 1,4-Cyclohexylene dimethanol (100 mol%)	34×10^{-6}	7×10^{-6}	6×10^{-6}	3×10^{-6}	O	O
2	"	26×10^{-6}	3×10^{-6}	5×10^{-6}	2.5×10^{-6}	O	O
3	"	19×10^{-6}	4×10^{-6}	4×10^{-6}	1.8×10^{-6}	O	O
4	"	23×10^{-6}	2×10^{-6}	5×10^{-6}	2×10^{-6}	O	O
5	Polycyclohexylene-1,4-dimethylene terephthalate	20×10^{-6}	5×10^{-6}	4×10^{-6}	1.8×10^{-6}	O	O
6	"	33×10^{-6}	6×10^{-6}	3×10^{-6}	2×10^{-6}	O	O
Comparative example 1	"	37×10^{-6}	8×10^{-6}	6×10^{-6}	3×10^{-6}	×	O
2	Terephthalic acid (85 mol%) Isophthalic acid (15 mol%) 1,4-Cyclohexylene dimethanol (100 mol%)	39×10^{-6}	9×10^{-6}	5×10^{-6}	3×10^{-6}	×	O
3	Polyethylene terephthalate.	17×10^{-6}	7×10^{-6}	12×10^{-6}	5×10^{-6}	O	×

It is apparent from the above results that tracking errors are improved as shown in working examples 1 to 6 for the samples in which the coefficients of temperature- and moisture-induced expansion are in a suitable range, and it is apparent that recording, playback, and other uses are possible for a magnetic disk in high-temperature, high-humidity atmospheres. In contrast, tracking errors occurred in comparative examples 1 to 3. Thus, it is apparent that the disc of the present invention has considerable industrial value as a flexible disc with high track density.

Effect of the Invention

In the flexible disc for magnetic recording of the present invention, the substrate is a special polyester, in other words, a polyester that has poly-1,4-cyclohexylene dimethylene terephthalate as the principal component and is biaxially drawn so as to provide balance in the lengthwise and width directions, and a magnetic layer is formed on the surface of this polyester film. When the substrate film is provided with predetermined coefficients of temperature- and moisture-induced expansion, tracking errors do not occur even if the track density of a magnetic disc is increased, so an advantage is provided in that high-density recording is possible. This magnetic disk is further provided with an advantage in that no tracking errors occur even when there is a difference in temperature and humidity conditions at recording and playback. The flexible disk of the present invention can endure variations in atmosphere and has a wide range of applicability.